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Soft Decision Decoding of Convolutional Codes in Direct-Sequence Spread-Spectrum Mobile Wireless Communications

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New uses of convolutional codes have been developed for nonuniform phase-shift-key (PSK) signaling. Soft-decision decoding of convolutional codes has been investigated for applications of nonuniform PSK modulation to multimedia signaling and multicast transmission in direct-sequence spread-spectrum wireless communication networks. Research has also been conducted on new processing techniques in PSK receivers to provide soft information for decoding of convolutional and turbo codes. Methods were also investigated for the development of soft-decision information in rake receivers for communication over fading multipath channels. Research was initiated on soft-decision decoding for turbo product codes.

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soft-decision decoding, receiver processing, multimedia modulation, fading channels, nonuniform phase-shift-key modulation

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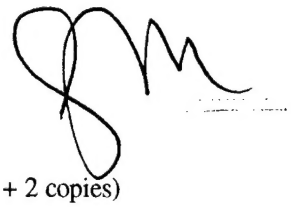

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FINAL REPORT

PROJECT TITLE: Soft Decision Decoding of Convolutional Codes in Direct-Sequence Spread-Spectrum Mobile Wireless Communications

Army Research Office Grant Number DAAG55-98-1-0013
ARO Proposal Number 37778-EL-DPS

ABSTRACT

New uses of convolutional codes have been developed for nonuniform phase-shift-key (PSK) signaling. Soft-decision decoding of convolutional codes has been investigated for applications of nonuniform PSK modulation to multimedia signaling and multicast transmission in direct-sequence spread-spectrum wireless communication networks. Research has also been conducted on new processing techniques in PSK receivers to provide soft information for decoding of convolutional and turbo codes. Methods were also investigated for the development of soft-decision information in rake receivers for communication over fading multipath channels. Research was initiated on soft-decision decoding for turbo product codes.

KEY WORDS
soft-decision decoding, receiver processing, multimedia modulation, fading channels, nonuniform phase-shift-key modulation

SCIENTIFIC PERSONNEL SUPPORTED AND HONORS, AWARDS, AND DEGREES

Faculty: Professor Michael B. Pursley
Graduate Students: T. G. Macdonald, J. van der Horst, J. S. Skinner

Degrees granted: J. van der Horst, M.S. in Electrical Engineering
T. G. Macdonald, Ph.D. in Electrical Engineering

Honors and Awards for T. G. Macdonald:
AFCEA Fellowship, 1998
College of Engineering and Science Outstanding Graduate Research Award, 2001
Clemson University Outstanding Graduate Research Award, 2001
Department of Defense MURI Fellow, 2000-01

Honors and Awards for M. B. Pursley:
IEEE Military Communications Conference Award for Technical Achievement, 1999
Clemson University Alumni Award for Outstanding Research, 2000
Honorary Member, Golden Key National Honor Society, Fall 2000
IEEE Millennium Medal, 2000
IEEE Communications Society Distinguished Lecturer, 2001-2002

REPORT OF INVENTIONS: none

SCIENTIFIC PROGRESS AND ACCOMPLISHMENTS

The processing that is often employed in receivers for quaternary direct-sequence spread-spectrum communications operates separately on the inphase and quadrature components of the spread-spectrum signal. Recent results on quaternary complex sequences provide a strong motivation to employ processing methods that permit the receiver to benefit from the correlation properties of the complex sequences. This can be accomplished through the use of complex processing and complex correlators in the receiver. We have developed receiver architectures that take advantage of the improved periodic correlation properties of the quaternary complex sequences. The outputs of the complex correlators will serve as the soft-decision inputs to decoders in the spread spectrum receiver.

We have shown that nonuniform phase-shift-key (PSK) signaling permits the transmission of multimedia information, and it also provides an efficient way to transmit multicast messages to receivers of different capabilities. Convolutional coding has been incorporated with nonuniform PSK transmission to improve the energy efficiency of the multimedia and multicast transmissions. Soft-decision decoding of convolutional codes has been investigated for applications of nonuniform PSK modulation to direct-sequence spread-spectrum wireless communication networks.

The characteristics of mobile wireless communication channels vary with time, and network throughput can be increased by adapting the modulation and coding to match the channel conditions. We showed that nonuniform PSK modulation can be used in an adaptive signaling scheme to deliver multiple messages with different requirements for quality of service. The signaling methods that we propose deliver a basic message at a specified error rate and simultaneously deliver an additional message by exploiting any extra capability that is available. We show that by adapting the location of the points in a PSK constellation, the throughput can be maximized for the additional message while maintaining an acceptable error rate for the basic message. Responses to larger changes in channel quality are accomplished by adapting the PSK constellation size, signaling rate, and error-correcting code. Examples of adaptive, nonuniform PSK signaling are presented, including an application to a cellular direct-sequence spread-spectrum multiple-access system, also known as cellular code-division multiple access (CDMA).

We obtained simple closed-form expressions for the probability of error for M-ary phase-shift-key (M-PSK) signaling over a channel with additive white Gaussian noise and nonselective Rayleigh fading. These expressions can be used to analyze the performance of standard uniform M-PSK constellations and nonuniform M-PSK constellations, which we have shown to be extremely useful for multimedia communication, multicast transmission, and adaptive signaling. We analyzed several systems that employ nonuniform M-PSK for multicast transmission over Rayleigh fading channels, and we determine the performance of nonuniform M-PSK with convolutional coding and soft-decision decoding.

One phase of research focused on military cellular CDMA with mobile base stations and handsets that employ soft-decision decoding with three bits of soft-decision information. The performance of a forward link that has interference from one or more neighboring base stations was evaluated. A multiple-cell mobile system was evaluated by simulation and compared with results on a single-cell simulation in which Gaussian noise is used to model the interference and shown to give very good accuracy for both hard- and soft-decision decoding. We believe this to be the first investigation of the accuracy of the Gaussian approximation for CDMA systems with soft-decision decoding.

Research was initiated on turbo-product codes. Our plan was to use a development board marketed by Efficient Channel Coding, Inc., to investigate the performance of iterated soft-decision decoding in direct-sequence and frequency-hop spread spectrum systems. Problems with the hardware hindered this work, and we were delayed by more than a year before these problems were overcome. We found it very difficult to find a computer that is compatible with the board. In spite of the recommendation from ECC to purchase a particular model of Dell computer, we found this computer is not compatible with the board. In the summer of 2001 we found a computer in which the ECC board could be used, and many simulations were completed prior to the termination of the grant. Preliminary results were presented at MIT Lincoln Laboratory in August 2001, where we exchanged ideas a research results with Lincoln Laboratory personnel who are using the development board for research on communications over fading channels. Unfortunately our request for a time-extension on the grant was denied, so the work on turbo coding will not be completed under ARO sponsorship.

TECHNOLOGY TRANSFER

Results on soft-decision methods were employed in ITT's Handheld Multimedia Terminal (HMT) that was developed for the DARPA GloMo project High Reliability All-Informed Voice Service for Handheld Multimedia Terminals within a Tactical Network. Discussions were underway with ITT concerning applications to JTRS when the grant was terminated.

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